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Development of a Mathematical Model of Business Process to Optimize the Budget Department's Work in Machine-building Enterprises

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Abstract

The article covers the highlights in the development of an optimal mathematical model of business process of the budget department's work in machine-building enterprises. There has been done the analysis of basic problems in the engineering field, arising in the course of economic instability and deterioration of the business strategy. The investigation discussed is aimed to improve the competitiveness in the market and optimize the strategy of the organization's activities as a whole. Special attention is paid to the methods of mathematical modeling of business process on the basis of queuing theory to develop the authoring mathematical model. The developed model would make it possible to evaluate and optimize the performance of the budget departments of engineering enterprises.

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1. Introduction

At the present time the unstable economic situation demands indispensable improvements in those business processes that have most influence on economic performances in the engineering industry. But in practice, approaches, applied to representation and improvement of production and implementation of business processes, in particular, the business process of construction projects in engineering, are not formalized [1]. The fact is that the well-ordered algorithm is lack, as well as, the mathematical formulation of the optimization process in the organization. The optimization will give a powerful impetus to thinking over the universal automation of the processes affecting the degradation of the whole organization. Besides, the important requirement is to improve the performance quality of the budget department and engineering organizations having regard to the competitiveness in the construction market and business efficiency index.

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The aim of the work is to develop a mathematical model of the business process of cost estimating on basis of economic and mathematical modeling. This aim would assess the significance of optimization and automation of the business process in the engineering industry.

2. Materials and methods

In the course of the work there were investigated the basic economic difficulties and problems having place in small-structured machine-building enterprises. Also, the analysis of problem-solving in the engineering business took place. Another important factor was to formulate the concept of business process and to review the main approaches to indicating business processes, where both, the concept of a mathematical model and a mathematical model of business process have been introduced [1–3]. The study has defined the basic concepts for developing a mathematical model of the optimization of the business process in question, using economic-mathematical methods, taking into account the authoring.

The study has examined the structure of a medium-sized engineering company and analyzed the principal business processes. Particular attention is given to key business processes within the subject area research of the engineering organization's structure. The economic-mathematical model of the business process of the budget department's work has been developed on the basis of queuing theory. The model has been justified as a means of increasing the budget department efficiency.

Conceptual framework of the problem discussed is considered as a number of objective regularities of business processes. These processes are presented as the queuing systems, according to the principles that identify the limits, structures and models of business processes.

A queuing system (QS) is defined as any system that intends for serving the arrivals, i.e. the system which, on the one part, receives mass requests (demands) for servicing, and on the other part, produces the responses.

The model of the business process of cost-estimating presented in Figure1 is an entity representing a detailed description of a number of interrelated activities as a queuing system (QS). The QS interprets the conversion of arrivals and responses in accordance with the optimum choice of the system's indicators to forecast the system behavior, taking into account the main objective of its operation.

In the planned model the input of the business process as QS means the number of orders (applications) to perform support building services. Among them a process of making up an estimate takes place, in order to evaluate current services, taking into consideration all the requirements of a specific customer. The service of the business process in QS stands for the staff with their working places and personal computers. They carry out requests, making up an estimate, with controlled quality and certain intensity. The queue of business process as QS is defined as the greatest possible number of all the customer requests that come in addition to those that are already in the process of drawing up documentation. The output of the business process as QS is represented with cost-estimate documentation, already drawn up and performed. The documentation is determined by quantitative indicators, which also correspond to the requirements of the customer, according to the regulations of the organization [5].

Furthermore, the model of the business process of drawing up the cost-estimate documentations of an engineering organization can be represented by a number of indicators. They are: the number of QS channels m, the average arrival rate λ, the average number of servers at the queuing node k. The QS can be considered as an equipment with a definite coefficient of probability ρ.

These indicators can be described with mathematical expressions, used to calculate the characteristics of business function items. The derived business functions of the business process can be considered as an open queuing system [4–6]:

1. indicators of business process state probability;
2. quantitative indicators of business process;
3. economic indicators of business process.

Basic mathematical expressions of probability and quantitative indicators for the description of the optimal business process model, which are based on the queuing theory [4, 5]:

Utilization factor:

$$U = \rho \left(1 - P_{\text{fail}}\right). \tag{1}$$

The average number of customers in the queue (average number of off-hook channels):

$$\overline{S} = mU. \tag{2}$$

The average number of servers at the queuing node:

$$\overline{k} = \overline{q} + \overline{S}. \tag{3}$$

The customer arrival rate of QS:

$$\gamma = \lambda \overline{S} \tag{4}$$

or:

$$\gamma = \lambda \left(1 - P_{\text{fail}}\right). \tag{5}$$

The average time a customer spends in the system (Little's law):

$$\overline{w} = \frac{\overline{k}}{\gamma}. \tag{6}$$

The average time a customer spends in the queue in QS:

$$\bar{t} = \overline{w} + \overline{x}. \tag{7}$$

Described formulae (1-7) can be used to calculate the characteristics of any open queuing system regardless of the number of channels, customer arrivals, the law of time allocation of services, etc. For open QS without any queue limits, the following formulae are used:

Utilization factor:

$$U = \rho. \tag{8}$$

System effective service rate:

$$\gamma = \lambda. \tag{9}$$

The outage probability (P_0), the probability of failure (P_{fail}) and the average queue length ($\overline{q}$) are calculated differently depending on the type of QS (in this case QS is with limited length of the queue).

The outage probability:

$$P_0 = \frac{1}{\sum_{i=0}^{m} \frac{\rho i}{i!} + \frac{\rho^{m+1}}{m!(m-\rho)} \left(1 - \left(\frac{\rho}{m}\right)^{n}\right)}, \tag{10}$$

where m stands for the number of QS channels; n is the greatest possible number of arrivals in the queue.

The probability of failure:

$$P_{\text{fail}} = \frac{\rho^{m+n}}{m!\, m^{n}} \cdot P_0. \tag{11}$$

The average queue length:

$$\overline{q} = \frac{\rho^{m} \left(\frac{\rho}{m} - (n+1)\left(\frac{\rho}{m}\right)^{n+1} + n\left([\frac{\rho}{m}\right)]^{n+2}\right)}{m!\left([1 - \frac{\rho}{m}\right)]^{2}} \tag{12}$$

On the basis of the examined indicators of the probability of the business process and its quantitative indicators, economic indicators, characterizing the operating efficiency, can also be calculated.

The economic indicators of the business process are those characteristics that can really represent incomes and costs, for example, the costs for servicing, etc. This is the result of an organization's production activities. It should also be noted, that the calculation of the economic characteristics data always depends on the exact problem statement [4]. Thus, it is possible to define the following economic indicators of the business process, which are rendered by the following formulae:

Revenue from business process response within the time T:

$$V = \gamma C T, \tag{13}$$

where γ stands for the business process capacity; C is revenue from customer's response.

The costs calculation that concern request servicing in the QS with m-services within the time T:

$$Z_{\text{serv}} = \gamma C_{\text{serv}} T, \tag{14}$$

where C_{serv} stands for the costs that are connected with servicing a customer.

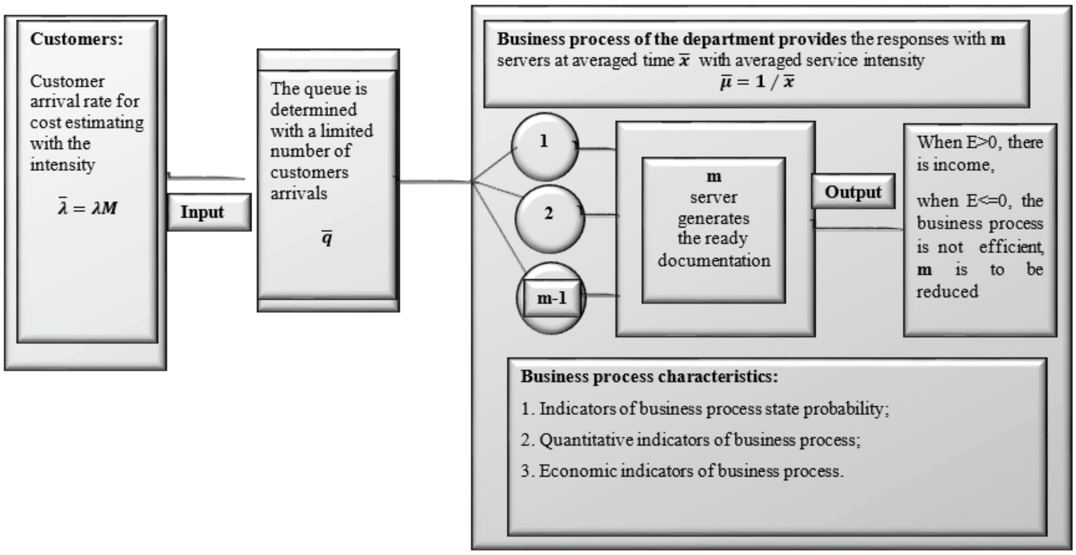

Figure 1: Structural and logical representation of the business process of estimating made by the budget construction department of the organization on the basis of queuing theory.

It is worth noticing that there are several restrictions of the business process model. With some degree of approximation we can assume that the current number of customers' arrivals of the prototype business process is Poisson. Moreover, with reference to the probability theory and the theory of random processes, the use of Poisson distribution provides the most stringent conditions for existing service systems. The business process of this type can have no more than n customers in the particular queue [6]. It follows that if a customer request arrives to be served at the moment when n customers are already being served in the queue - it will not be served and, accordingly, will be cut off the queue.

For this business process, presented as queuing system, there may be such number of service m, that, in case one service is added, costs for losses may not exceed the profit from their introduction [6]. But, the fact is, that the current costs service Z_{serv} may increase to some degree if one additional service (staff, workplace) is introduced. It should also be emphasized that, if the costs of one additional working service input (m + 1) are saved at m level, costs may be cut down for every service of the business process (wages or the main work process support funds). It is obvious to assume that the reduction of costs for any particular kind of working service can lead to the risk of substantial losses. Therefore, it is necessary to use part of the profit, which was obtained at service input, to offset arising losses. From the above we can conclude that a significant increase in the number of services working in the process described will be beneficial as long as the costs for losses do not exceed the profit from the service input.

Therefore, the costs of customers being served with extra serving system (workplace) can be defined as follows [4]:

$$Z_{\text{serv}}^{m+1} = z_{\text{serv}}^{m} + \Delta z^{m,m+1}, \tag{15}$$

$$\Delta z^{m,m+1} = \frac{Z_{\text{serv}}^{m}}{\frac{m - z_{\text{serv}}^{m}}{m+1}} \cdot (m+1), \tag{16}$$

where z_{serv}^{m} stands for costs of customers being served with an extra serving system (e.g. working place) in a line, excluding loss compensation;

$\Delta z^{m,m+1}$ stands for the value of loss compensation with extra serving systems in a line.

It is possible to calculate the income of the business process, which has been obtained as the result of customers servicing:

$$D = V - Z_{\text{serv}}. \tag{17}$$

The indicators of economic effect occurring with an extra service in the business process can be calculated as:

$$E = D_m - D_{m-1}. \tag{18}$$

The analysis of indicators of economic effect can identify two main criteria:

- $E > 0$, the criteria at which business process as a whole brings a good income when additional service is introduced,
- $E \leq 0$, the criteria at which there is no profit and the introduction of additional services is inefficient.

3. Results and discussion

In the process of developing a mathematical model it is worth noting, that the calculation of economic effect will reflect the actual results at optimizing the system parameters in case the number of services is being changed [5]. Moreover, the choice of the optimum alternative of the system functioning can be carried out under the following conditions:

$$\begin{cases} P_{\text{serv}} \to \max; \\ 0.75 < U < 0.85; \\ D \to \max. \end{cases}$$

Thus, the above indicators (1-18) are the basis of a mathematical model of the business process of budget department of an engineering organization, regarding as QS with limited queue length.

The model in question has become the principle authoring system (Figure 2), which involves a staged analysis of business processes in order to define optimal parameters. Therefore, a simulation model of QS is an algorithm, reflecting QS behavior, i.e. the behavior in the period of specified customers arrivals, entering the system input.

The methodology of identification and optimization of a business process of an engineering organization has been applied for making an estimate and budget forecasting for LLC “TobolStroyService”. The principle aspects of the methodology are realized in Table 1.

It is worth mentioning that it is possible to define the total optimal parameter of the business process of an organization in the large.

Thus, in the course of conceptual modeling the optimal parameters of the business process have been found. The regular labor force makes up 7 workers, the utilization factor is 0.796; probability of servicing is up to maximum – 0.97. All the data above were obtained according to the applied methodology. But, it is worth noticing, that

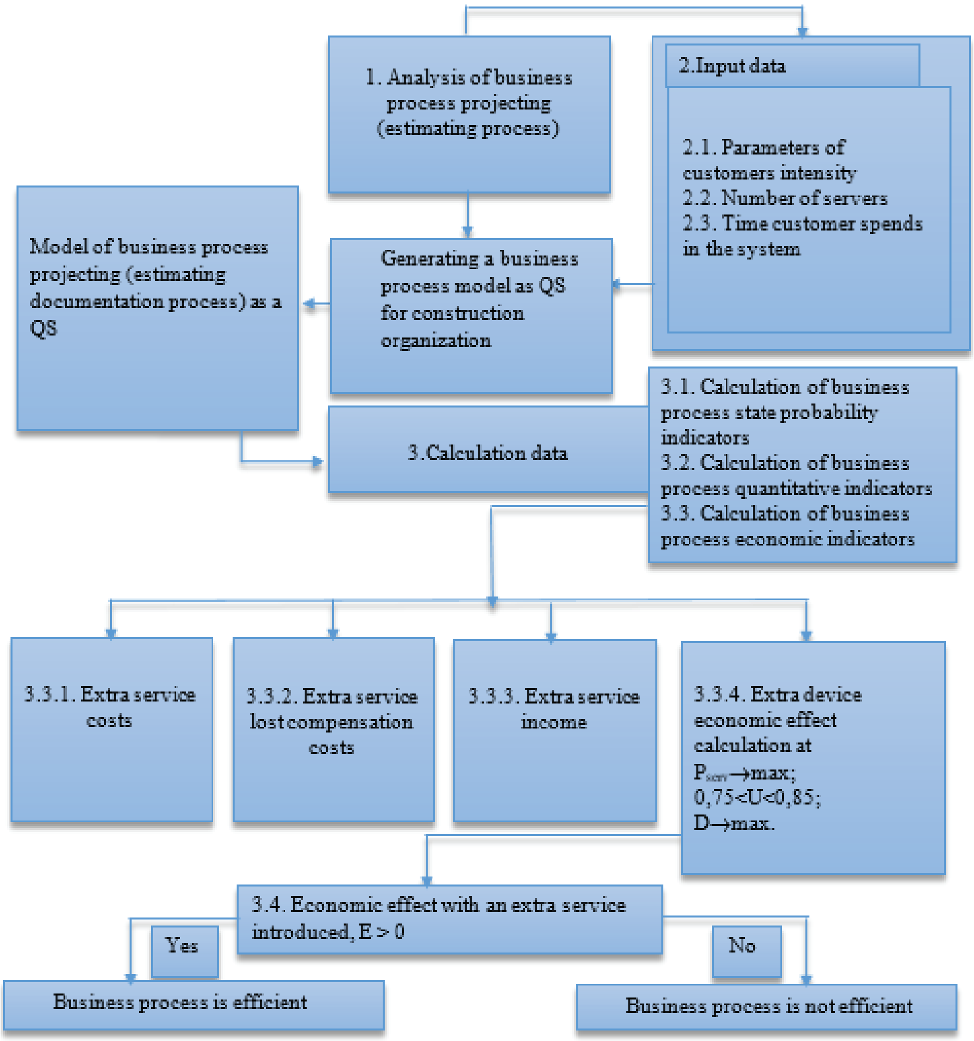

Figure 2: The methodology of identification and optimization of a business process of an engineering organization.

more exact results can be obtained while developing the specific program of simulator with preset parameters.

4. Conclusion

In the course of the study a mathematical model on the base of queuing theory has been developed. The model reflects the whole work of the estimate process as a part of the production structure of an engineering organization. In accordance with the developed model, the main indicators of optimization of business processes such as quantitative indicators and economic probability have been identified and described. These indicators provide the basis for the development of unique methods of their

Table 1: The methodology principle aspects realized on the example of business process of estimate documentation drawing up of LLC “TobolStroyService”.

Parameter	Actual process state at m=4	Predicted results of business process behavior with extra M channels				
		m=5	m=6	**Optimum alternative m=7**	m=8	m=10
1	2	3	4	**5**	6	7
1.Process capability P_{serv}	0.69	0.82	0.92	**0.97**	0.99	0.999
2.Utilization factor U	0.982	0.943	0.874	**0.796**	0.706	0.571
3.Customer arrival rate γ (per day)	5.5	6.6	7.3	**7.8**	7.9	7.99
4.Customer being served revenue in production system (V), thousand rubles	104.8	125.7	139.1	**148.6**	150.5	152.2
5.Customer being served cost in production system Z_{serv}, thousand rubles	15.8	19.8	23.7	**27.7**	31.6	39.5
6.Organization revenue D, thousand rubles	89.0	105.9	115.4	**120.9**	118.9	112.7
7.Economic effect with an extra M channel, thousand rubles	-	16.9	9.5	**5.5**	-2.0	-6.2

assessment and optimization. Moreover, they served as the basis for computer simulation in choosing the optimum number of serving workplaces and the improvement of run-time of the business process.

The main advantages of developing an optimal mathematical model practicing the economic-mathematical apparatus can be distinguished as the following:

- a detailed record of the correlations between the input and output parameters of the system;
- the absence of a requirement for a large number of input data;
- realization of business process optimization according to preset parameters in real time.

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